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16. Abstract

Discussion of the factors affecting the temperature of a solid or oceanic surface of a planet and the adjacent layers of the atmosphere. The relation between the temperature of a planet and the types of organic life forming on it is pointed out. It is shown that the temperature decrease with increasing height of the atmosphere is proportional to the force of gravity and inversely proportional to the specific heat of the gas. It is found that the greater the height and the transparency of the atmosphere and the blacker the soil of the planet, the greater the temperature of the lower layers of the atmosphere.

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THE TEMPERATURE OF PLANETS

K.Ye. Tsiolkovskiy

There are millions of billions of planets in the known universe. In essence, they are the cradle of organized life. The temperature of the solid surface of the planet that is in contact with the atmosphere has great significance in its development and existence. /97*

These are the conditions for life. 1. The existence on the solidified surface of the planet of liquids and gases, since organic life is associated with mobility and mobility is difficult in solid bodies. A fluid nullifies the crushing force of gravity. Together with an atmosphere it renders solar radiation harmless. 2. A moderate temperature; for otherwise excessively stormy movement forms, which destroys the delicate rudiments of complex organic compounds, i.e., the rudiments of life.

Only planets with a diameter of several thousand versts or more have a gas blanket and liquid. This is due to the fact that the light materials of great planets cannot penetrate into their central parts and chemically combine with them, and therefore an excess of them remains free. The excess forms atmospheres and oceans. In addition, the gases of a small planet, whether or not they manage to combine with the metals, cannot be held by the weak force of a small planet.

*Numbers in the right-hand margin indicate pagination in the foreign text.

The bigger the planet is, the more free gases remain and the richer its atmosphere.

Also, the first planets that separated from the sun are more abundant with gases since they separated from the surface of lighter parts of the sun. Nevertheless due to the smallness of the planets they do not retain this gaseous richness - their small force does not suffice.

Excessively large planets are not favorable for organic life for the following reasons. 1. They slowly cool off and therefore by the time they have sufficiently cooled off they are far from the sun and its rays have already become useless and impotent for creating life. 2. Thick atmospheres darken even this weak light. Nocturnal and deep darkness are not able to generate organic life. If there is life in the darkness of the ocean depths, then indeed its basis is in the corpses of surface vegetation and animals that fall to the bottom. 3. The immense atmosphere, as a result of the irregularly heated soil (for example, the red spot on Jupiter), /98 causes stormy winds and disturbances that kill life. 4. The first planets that separated are formed from gases and are therefore unsuitable (for example, Neptune). 5. The last are unsuitable due to the hardness of materials and the lack of gases (for example, Mercury).

We will analyze here only the causes on which the temperature of the solid and oceanic surfaces of a planet and of the adjoining layers of the atmosphere depend.

We note that a high temperature as well as a low temperature still does not present an obstacle for the development of life. Actually, for high temperatures all the physical and chemical properties of the elements change and no longer would the same elements

that prevail for us on Earth be part of the animals and vegetables: they are not suitable and would not be able to give life. The simple substances that are suitable for it and their chemical compositions will already differ. The bioelements of each planet depend on its temperature. Depending on its temperature, all 92 elements or part of them could be part of the substances of the animals and vegetables: on one planet 12 of these simple substances, an another - 15 quite different ones, etc.

Sharp variations of temperature on a planet are also not favorable for the rudiments of complex organic substances since, in addition to other things, they cause violent movements in the atmosphere and the oceans. Favorable conditions are: 1) a small eccentricity of orbit (circular motion) - then there will not be sharp changes of temperature except at the equator; 2) a small incline of the axis of the planet toward the ecliptic - this causes no winter cold period and no summer hot period: a large eccentricity of the annual orbit makes these thermal variations unbearable; 3) a short year, which weakens the sharpness of the seasons, is useful; 4) a short period of rotation or a short night is also favorable since the night cold kills those organisms that have not adapted (example - the Moon, Mercury).

Even if one part of a planet can give a mechanical calm, a small variation of temperature and a moderate influence of the rays of the central light source, for we can find all this at the equator, between hills that shield the wind and in small lakes, it would still be necessary that: 1) the day is short; 2) there is almost a circular planetary orbit, and; 3) there is a small incline toward its planetary axis of rotation.

Here complicated organic substances and the first protoplasm

can be established under the influence of the rays of the sun, which have been weakened by the atmosphere and liquid.

A mature organism, completely formed although microscopic, can endure all variations, but its embryo is quite a different matter: here, namely, it is necessary to have the most insignificant fluctuations and variations. And billions of years are necessary for the formation of embryos.

We repeat about the significance of temperature: it changes only the selection of the bioelements.

Suppose there is a high temperature. On this temperature will depend only the selection of the life's elements from the 92 that the universe grants us. But it is necessary that this temperature does not fluctuate excessively. We expect it. What kind of temperature do we assume at the equator for the indicated favorable conditions? On what does the average value depend? /99

This is very interesting to know since the temperature determines the choice of the bioelements on which the animal and vegetable world of the planet depend. Perhaps on some planets gold, silver, silicon, aluminum etc. will be used for this, on others titanium, tantalum, chlorine etc. (In his interesting and scientific works astronomer L. L. Andrenko shows that carbon in the organic world of other planets can be replaced by silicon, and in general he chemically develops this idea of bioelements in detail).

Thus we find in the cosmos an infinite variation both in the temperatures of creatures and in their composition and properties. Until we can judge this last idea scientifically we can only assert their variation. The rest is, in the best case, a clever fantasy.

The planetary crust has solidified, but this does not prevent it from being very hot, even incandescent to the point of giving off its own light. In such a case it is possible to neglect the heating influence of the central source of light (the sun). The temperature of the planet will be very high independent of the solar distance. Gradually it will drop until it gives a sufficient calmness to the mobile parts of the planet and until it causes the generation of organisms.

The moment approaches when the internal heat of the planet first compares with the influence of the solar rays, and then it becomes quite insignificant, as on our Earth (as is well known, the temperature of the latter is determined almost solely by solar radiation).

Let us examine this moment.

In its spiral motion each planet in the course of a billion years moves further from the sun and gets less and less radiant energy from it. It is understandable that the average temperature of a planet will above all depend on the distance of the planet from the sun. This means that for any given planet the temperature depends on the time of its existence and on the internal energy of the sun.

Imagine a given planet with a given atmosphere, oceans, etc. It receives a quantity of solar heat and, as a consequence, the average temperature still depends on the properties of the surface of the planet. Part of the radiation falling on it is reflected by the solid surface, liquid and gas. We can imagine an ideal mirror-like surface for the planet where all of the heat of the sun is reflected, returns to space, and the temperature of the planet approaches absolute zero in spite of the proximity of the sun.

On the other hand, for a planet with an ideally black surface its temperature reaches the possible maximum depending on the intensity of the solar rays.

In practice the reflectivity of a planet (albedo) varies approximately from 15 to 80%. But it is possible to artificially make it greater or less. However this is possible only for a numerously populated planet with technical power, when on each are (100 sq. meters) of land or water there must be no less than a pair of people.

Such power and such a population density have probably been attained by the majority of planets, since The Milky Way has existed for a long time and the planets should have matured. /100
There the temperature is dealt with according to desire rather than according to necessity. In any case it is economical to have a transparent or rarified atmosphere in order to use as great a part of the energy of the sunlight as possible. The average temperature of the planet, for a given absorptivity, still depends on the thermalconductivity of the layers that are being warmed. Thus, for a good thermalconductivity it is greatest, while for the least or average thermalconductivity the temperature is less because there are sharp variations of temperatures and a large loss of heat.

If a planet does not have an atmosphere then the temperature for identical conditions of the soil would not depend on the height of the place: in low areas it would be the same as in high mountains. But an atmosphere changes the entire matter.

Actually, in any gravitational column of matter, and in particular, of gas, the force of gravity increases the temperature of its lower parts and decreases the temperature of its higher parts.

Therefore the layers of the atmosphere are colder the higher one goes. Their coldness cools even the mountain tops.

It takes a culture and a power in forces to level the surface of a planet, and then only the lower layer of the atmosphere which adjoins the soil and the ocean would have any significance for us. What would the temperature be and how much would it depend on the depth of the atmosphere, its density and composition?

This, in part, was explained in my work "The Second Law of Thermodynamics". Here I shall briefly repeat only the main point.

Let us assume an atmosphere that is transparent, i.e., without dust or clouds, a uniform soil, for example a black soil or a soil covered by similar vegetation, and a surface that is uniformly luminated.

The rays of the Sun warm the surface of the Earth depending on its properties. The layer of the atmosphere adjacent to the soil becomes the same temperature. Higher, due to the influence of gravity, the temperature will decrease. This decrease depends on the force of gravity and the specific heat of the gas. It little depends on the density of the atmosphere and is proportional to the altitude of the layer under consideration and to the force of gravity. It is inversely proportional to the specific heat of the gas.

For example, in a hydrogen atmosphere the decrease would be 16 times less than in an oxygen atmosphere. On Jupiter it would be 2.5 times greater than on Earth, and on our Moon it would be 6 times less than for us. The higher the layer of gas, the more significant the decrease.

All of these conclusions, however, are complicated by the movement of the atmosphere, by the effects of radiation and by the

non-uniform thermal-transparancy of the rarified and thick layers of the atmosphere.

Thus, for a terrestrial atmosphere, according to my formula, we would find a decrease of 14 degrees Centigrade at an elevation of one kilometer. In actual practice it is around 5 degrees. In addition, at elevations around 10 kilometers it decreases and nears zero, i.e. the temperature above the troposphere does not decrease.

This is explained by the fact that two streams of radiation, /101
which are constant in force, warm the upper rarified and cold layers of the atmosphere. One stream of radiant energy comes from the sun, the other comes from the soil and the lower warm layers of the atmosphere. It is possible that the extremely rarefied atmosphere is warmed more strongly on account of its rarefication especially by the violet and ultraviolet rays of the sun. This is by day. But by night, perhaps, the decrease of the temperature continues even in the stratosphere, although not very strongly due to the radiation of the warm Earth. This explains the theoretical deviation of the decrease from 14 to 5 degrees, i.e. the continuous stream of radiant energy which warms the upper layers of the air at the expense of the lower. By day the influence of the sun is further added.

Thus, the atmosphere reflects part of the solar rays and this part (albedo) fluctuates from 0 to 100% - in the limit. If this were not so, then the soil would absorb the rays and the average temperature of the planet would increase. On the other hand, the upper layers of the atmosphere absorb some quantity of solar energy. This absorption can also fluctuate from 0 to 100%.

As a result of this absorption the upper boundaries of the

atmosphere can warm up to some temperature, and, we assume, up to 0 degrees Centigrade. From here its increase will depend on the force of gravity and the specific heat of the gas. Let this increase be 5 degrees Centigrade for each kilometer deeper into the atmosphere.

It is clear that the temperature of the layers of the atmosphere that adjoin the soil will be higher the greater the depth of the atmosphere. If, for example, the depth is 10 kilometers, then the temperature of the lowest layers of the atmosphere would be 50 degrees Centigrade.

The upper, extremely rarefied layers of the atmosphere are very cold and therefore the heating of the atmosphere, for example, to zero, will be not on its surface, but at some depth. Therefore in calculating the increase of warmth we will consider only the lower portion of the atmosphere (by convention - the troposphere). But indeed the troposphere for different planets can have a very diversified interior depending on its mass and density.

In this way we see that the higher the atmosphere, the more transparent it is and the blacker the soil, then the greater the temperature of its lower layers (or the surface of the planetary crust). Thus large planets with rich atmospheres that have moved far away from the sun can have a higher soil temperature than small planets with rarefied atmospheres, a small force of gravity and are near to the sun.

Moreover, the composition of the atmospheric gases exert an influence. Gases that are less elastic (carbon dioxide, chloride and many complex gases) with a high specific heat give a greater decrease of temperature for each kilometer of elevation and, consequently, a higher temperature of the soil. Moreover, some gases

easily pass rays with a high refractivity (just as glass) and hold back the ground rays of a low refractivity. This also contributes to an increase of the planetary temperature.

Our planet once had a very rich atmosphere composed almost entirely of carbon dioxide alone. Then its temperature was high everywhere, in spite of the semi-darkness and the sparseness of the /102
solar rays that penetrated to the surface. The albedo was immense, and the Earth received little of the solar energy; the atmosphere retained the heat.

The known degree of heat is favorable for the development of an organic world, but the sparseness of solar energy weakens the vegetative world, and, accordingly, the animal world. The high temperature is not very favorable for them when there is no solar energy or when it was absorbed by the correct layers of the atmosphere or reflected off of it.

An intelligent being, becoming acquainted with nature and learning her laws, ventures to get not only a high percent of solar energy but also a desirable temperature. But this subject does not form the theme of our present work.